

Applications in Prestressed Wood



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R. Taylor

Associate Research Engineer
Research and Development Branch

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For additional copies, contact:
The Editor, Technical Publications
Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8

Telephone: (416) 235-7635
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Applications in Prestressed Wood

Author:	R. Taylor
MTC No.:	SRR-87-07
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Abstract:	The concept of prestressed laminated wood decks was conceived in Ontario in 1976 as a method of upgrading existing deteriorated nailed laminated wood decks. The success of the system as a method of rehabilitation prompted considerable research and development aimed at introducing it into new construction. This led to the formation of a comprehensive set of design specifications which have since been adapted into the Ontario Highway Bridge Design Code and were included in the 1983 edition. Since its inception in 1976, the prestressed wood concept has been used many times, and by 1985, a total of at least 16 bridges used the concept in various ways. The objective of this paper is to discuss a number of these field structures in order to demonstrate the flexibility of the prestressed wood deck system. In new construction, the system has been applied to both longitudinally and transversely laminated decks including both on-site deck assembly as well as a pre-assembled deck panel system. The paper summarizes the applicability of the system, construction sequence, and field problems. In addition, a discussion is provided concerning construction costs for some of the applications as derived from the field structures.
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1/ INTRODUCTION

The concept of prestressed laminated wood decks was conceived in Ontario in 1976 [1] as a method of upgrading existing deteriorated nailed laminated wood decks. The success of the system as a method of rehabilitation prompted considerable research and development [2] aimed at introducing it into new construction. This work led to the formation of a set of design specifications for prestressed wood decks that have been adopted into the latest Ontario Highway Bridge Design Code (OHBDC) [3].

The objective of this paper is to emphasize the applicability of the prestressed wood system in rehabilitation and new construction. Since its inception in 1976, the prestressed wood concept has been used many times, and by the end of 1985, a total of 16 bridges utilized the concept in various ways. This paper presents a number of the field applications covering both rehabilitation and new construction. The discussions centre upon the applicability of the system, construction sequence, field problems and, where possible, the projected costs.

2/ THE PRESTRESSED WOOD SYSTEM

The prestressed wood concept utilizes laminated dimension lumber held together to form a continuous structural medium by applying pressure perpendicular to the laminates. This pressure creates sufficient friction between the laminate surfaces to ensure that they participate, under loading, as an efficient load sharing system [2].

The OHBDC [3] contains the first published design specifications for prestressed wood. However, due to ongoing research and development activities, these 1983 specifications are now limited in scope. An MTC design report [4] dealing with prestressed wood was revised in 1984 to include some of the more recent developments.

2.1/ Internal System

There are two prestressing arrangements that have been successfully applied in the field, both of which are covered by the OHBDC specifications. The internal system depicted in Figure 1 is applied to new construction. The laminates are predrilled so that after assembly the prestressing bars can be passed through the decks and anchored to the steel bulkheads. The bulkheads consist of continuous heavy steel channels supplemented at the bar locations by individual steel plates which bear directly against the web of the channel.

2.2 External System

The external system, shown in Figure 2, is applied to the rehabilitation of existing nailed decks where drilling of holes through the deck is not possible.

Pairs of bars are used, one above and one below the deck, and are anchored to the heavy steel plates which project above and below the deck, as shown in Figure 2. These plates bear directly on the flanges of the continuous steel channels. To ensure uniform transfer of the prestressing force to the channel, the webs are stiffened directly beneath the anchorage plates.

2.3/ Environmental Protection

The OHBDC requires that the bars and their accompanying hardware be hot-dip galvanized for both the prestressing arrangements previously described. Considering the sensitivity of high strength steels to heat treatments, this hot-dip process must follow the direction of the bar manufacturer. Epoxy coating was applied on one structure, as will be discussed later, but did not prove to be practical.

The bars of the internal system require, at present, no further efforts towards bar protection other than galvanizing. The bar within the deck is considered to be adequately protected against direct moisture access and physical damage.

The bars of the external system, however, must be enclosed in sealed conduits equivalent to the arrangement shown in Figure 2. Since the deck will change dimension, become narrower, under prestressing this conduit must be able to change length while maintaining its capacity to prevent moisture access. The arrangement portrayed in Figure 2 using Neoprene "O" rings has proved to be practical in application though no post construction inspections of bar conditions have yet been performed.

3/ REHABILITATION OF EXISTING NAILED DECKS

Since the first application of the prestressed wood concept on the Hebert Creek Bridge in 1976 [1], eight other existing nailed laminated decks have been rehabilitated using the same technique. A list of these bridges is provided in Table 1.

The following discussion reviews some of these field structures by way of presenting the construction process. Various problems are presented along with the modifications which were subsequently applied to resolve them. A fairly lengthy description of the rehabilitation of the Hebert Creek bridge is given to provide the overall procedure which was similar on all bridges. Subsequently, several of the other bridges are presented highlighting only the modifications that were applied.

3.1/ Hebert Creek Bridge, 1976

The Hebert Creek bridge was treated as a prototype structure directed by the Research and Development Branch of MTC. Therefore, it was analysed and load tested extensively, and the results of this work are documented in Reference 1. Figure 3 summarizes the load test results, in terms of midspan deflection. The tremendous improvement in the structural response due to prestressing, indicated by these results, is what prompted the subsequent development of the system to its present status.

The prestressing system, described by Figure 2, is the result of a number of years of development, primarily derived through field applications. The system used on the Hebert Creek bridge in 1976 was considerably more simple. The pairs of high strength bars were attached to heavy steel plates, but no steel channel was used and the plate bore directly against the wood deck. The bars were enclosed in PVC tubes running the full width of the deck except for about 150 mm of free movement at each end to allow for narrowing of the deck as it was squeezed together. These PVC tubes were pre-filled with heavy grease to protect further against moisture penetration. The top bars of the system were installed in grooves cut into the asphalt, as shown in Figure 4, in order to maintain traffic flow while protecting the bars and pipes against damage. Squeezing the deck together destroyed the original holding power of the toe nailing

which held the laminates to the pile bents. However, no apparent damage to the timber was observed in these areas during prestressing. Afterwards, the deck was resecured to the pile bents using simple steel clamps similar to those shown in Figure 5.

The transverse prestressing of the bridge, though successful, brought to light a number of difficulties that would require particular attention. The anchorage plates bearing directly against the wood proved to be unsatisfactory as shown by the local crushing of the wood in Figure 6. Narrowing of the deck due to the closure of spaces between the laminates far exceeded the original estimate, reaching as high as 450 mm at some transverse sections. This created problems with the PVC tubing which pushed up against the backs of the anchorage plates and had to be trimmed in the field.

The installation of the top bars by cutting into the asphalt was an effective method of maintaining traffic flow while protecting the bars against direct damage. However, the asphalt was severely broken by the traffic and resulted in a poor supporting medium for the new asphalt overlay. Though each of the top pipes were secured to the wood deck with several pipe clamps prior to asphaltting, this appeared to be insufficient hold down as reflective cracking occurred above many of the pipes after a short interval.

The jacking operation, by which the high strength bars were tensioned, used only two jacks. This turned out to be a very slow procedure as the initial effects of tensioning the bars at one location were very localized. The subsequent tensioning of adjacent bars actually loosened the previous ones. It took five complete passes along the 17 pairs of bars to reach a point where some level of force was maintained in each bar. Another seven passes were required to reach the maximum force which was limited by the localized crushing of the wood. The estimated time required to complete this operation was about 4 working days or 12 man-days.

3.2/ Kabaigon River Bridge 1979

In 1979, two bridges were rehabilitated by transverse prestressing as indicated in Table 2. Only the Kabaigon River Bridge utilized any significant modifications. The prestressing arrangement was identical to that used on the Hebert Creek bridge, except that a heavy steel channel bulkhead was installed beneath the anchorage plates, as shown in Figure 7.

This worked extremely well and after reaching the full 270 kN force at each pair of bars, there were no visible signs of crushing of the wood or deformation of the channel. To offset the effects of narrowing of the deck four new laminates were added to each side of the bridge as can be seen in Figure 7. This represented an increase of about 2 to 3 percent of the overall deck width and proved to be a good estimate of the total deck movement.

The bars were protected by PVC pipes again, but this time, the free movement provided at each end was about 350 mm. This increase in movement called for larger steel sleeves into which these PVC tubes would slide. The rigidity of these long steel sleeves accentuated any tendency of the anchorage bulkhead to rotate and where rotation did occur, it caused binding of the arrangement as shown in Figure 8. The bars were also epoxy coated as can be seen in Figure 7, however this was not very successful. The coating was very sensitive to damage through handling, and it also prevented free movement of the threaded anchorage nuts and related hardware on the bars. Eventually, the coating was removed in the field to allow the anchorage nuts free movement.

The Kabaigon River bridge also provided the means for demonstrating the watertightness of a prestressed wood deck as can be seen in Figure 9. Shortly after prestressing, a rainstorm flooded the deck and the water would not drain away. Eventually, some holes were drilled to allow the water to escape so that the work could continue.

3.3 Pickerel River Bridge, 1982

The rehabilitation of the Pickerel River bridge was the first to utilize all of the current recommended details and procedures. This included the

complete removal of all asphalt to facilitate the installation, as shown in Figure 10. A two-way plank surface was installed which allowed for traffic to flow, while accomodating the top layer of bars beneath the running surface.

The prestressing system itself was detailed according to Figure 2 which provided for free movement of the protective tubing near the centre of the deck where it could not bind. The Neoprene "O" rings were used to seal the arrangement. The bars themselves were galvanized, and although they suffered no adverse damage during construction, the coating material still caused threading problems.

A new multi-jack hydraulic system developed by MTC was first applied at the Pickerel River Bridge. The arrangement is shown in Figure 13 as it was used at the Valentine Creek Bridge in 1985. The system uses one 530 kN capacity jack to tension both bars at once. The system includes 24 of these jacks with a common hydraulic supply and can prestress a bridge with up to 48 pairs of bars in just one day.

3.4/ Construction Costs

Up to and including the Pickerel River bridge, the work was always performed by so-called "in-house" forces. In these cases, it is difficult to derive construction costs although at the time of the rehabilitation of the Pickerel River bridge a figure of \$200 to \$250 (Canadian) per square metre was proposed.

The Tomstown Bridge, near North Bay, was the first rehabilitation to be performed entirely under contract. The construction cost was estimated to be \$240 per square metre which included a new asphalt surface. The Valentine Creek bridge, near Hearst, was also rehabilitated under contract and its construction cost was about \$295 per square metre. This cost included additional items such as temporary concrete barrier walls, additional traffic control, and new permanent concrete barrier walls after prestressing. Due to its remote location and the subsequent transportation costs, the new asphalt wearing surface on the Valentine Creek bridge constituted nearly one quarter of the cost of the contract.

Presently, a reasonable cost estimate for this form of rehabilitation should be between \$250 to \$300 per square metre including re-asphalting.

4/ NEW PRESTRESSED WOOD DECKS

A total of ten new prestressed wood decks have been constructed utilizing the concept, as shown in Figure 1. A list of these bridges is given in Table 2. The laminates are predrilled and trimmed to specified lengths so that the holes line up after assembly to accommodate the internal bars. With the exception of one bridge, no hole alignment problems were encountered during the laminate assembly. The overall lengths of the bridges are given in the table and the longest continuous deck with no breaks was on the Sioux Narrows bridge at 120 m. The following discussion provides a brief review of some of these new applications in terms of applicability, advantages, disadvantages, and where possible, construction costs.

4.1/ Fox Lake Road Bridge, 1981

The Fox Lake Road bridge was considered the prototype application of the new prestressed deck. Designed by MTC and constructed by the Ministry of Natural Resources (MNR), it was part of an MTC research project which included field testing [5].

The bridge, shown in Figure 12, is a framed structure with inclined legs and is supported on concrete abutments and footings which are anchored to the exposed bedrock formations. This simple structure is composed of prefabricated individual laminate frames as shown in Figure 13. The deck laminates are 38 mm x 286 mm and the legs are 38 mm x 184 mm. These frames were assembled side by side so that the bars could be passed through the holes in both the deck and the legs. Subsequently, the entire bridge was prestressed at one time. The jacking of the bars, as displayed in Figure 14, used the same multijack hydraulic system as before. The jacks were originally selected for both internal and external prestressing systems and are hollow cylinders which can accommodate up to a 50 mm diameter bar through the centre. A detailed documentation of the construction and testing of the Fox Lake bridge is provided in Reference 5.

The advantage of this structure over the conventional steel girder bridge generally used by MNR was related to cost. This prototype structure

reportedly cost only two thirds of that estimated for the bridge originally designed for this site.

4.2/ New Decks on Old Truss Bridges

The application of a new stiffer and more durable prestressed wood deck has gained popularity as a deck replacement on old truss bridges.

Its application at the Sioux Narrows bridge, in 1982, provided distinct advantages over the old nailed deck that the bridge originally supported. The new longitudinally laminated, transversely prestressed, wood deck was used to replace the old transverse laminated deck as shown in Figure 15. This reorientation of the deck laminates, coupled with the higher stiffness of the prestressed deck, improved the longitudinal load distribution of the bridge deck system. This resulted in the reduction of a critical overstress condition in the mainspan floor beams to within acceptable levels.

The new two lane deck was installed in two halves in order to maintain a single lane of traffic at all times. The bars of the resulting halves were then coupled together at a permanent common bulkhead along the centreline of the bridge and jacked together to form one continuous two lane deck. The new deck supports a new unbroken asphalt surface over its 120 m length where before the old nailed deck surface required continuous maintenance. A detailed report on the design, construction and testing of the Sioux Narrows bridge is available in Reference 6. The estimated construction cost for the new deck, including new asphalt curbs and guardrails, was about \$370 per square metre.

In the case of old steel trusses, the use of prestressed wood deck, as shown in Figure 16, can greatly improve the overall load carrying capacity. Preliminary calculations can show that for spans over 40 m the use of a wood deck instead of a concrete deck can reduce the overall dead load forces in the trusses significantly. The new wood deck is supported directly upon the transverse floor beams and requires only a few steel stringers to be left in place to maintain some rigidity until the new deck is secured to the steel. It is important to note that a new

concrete deck must be at least 225 mm thick [3] to accommodate the necessary reinforcing steel resulting in a dead weight of 5.4 kN/m². A wood deck of 240 mm depth weighs only 1.44 kN/m² and can reach a span between floor beams of at least 6 m. No cost estimates for this form of replacement were available at the time of publication of this paper.

4.3/ Transverse Laminated Wood Decks

The most common form of wood deck is the transverse laminated deck supported on longitudinal girders or stringers. However, the practicality of prestressing such a deck delayed its application until a successful method was conceived in 1983. The practical problem arises from the increased instability of the shallow wood deck due to the longer prestressing length. For a reasonable girder bridge, of a 40 m span for instance, a shallow transverse laminated wood deck would be prestressed over the 40 m length and stability under the high prestressing forces would be questionable.

The first application of a prestressed, transversely laminated deck was performed at the Aquasabon River bridge in 1983. Panels of transverse decking, of about 5 m long, were preassembled and prestressed. A panel was then placed on the supported girders at one end of the bridge, as shown in Figure 17, and the bars were then retensioned a final time. The panel was subsequently tied down to the supporting girders and another panel placed in-line. The bars of the latter panel were temporarily released and the anchorage nuts at the trailing end of the panel were removed. The bars of the new panel were coupled to the previous one and the two were stressed together to form a continuous deck and the new portion was then tied down. This segmental procedure was performed over the whole bridge length resulting in a 42 m long continuous deck. The construction procedure was delayed somewhat by the failure of a number of high strength couplers used to connect panels together.

The design of the Aquasabon River bridge did not take advantage of the stiffer performance of the prestressed deck over the traditional nailed deck, because at that time, no design criteria were available. However, more recently the East Abinette River bridge and the Witch Doctor Lake bridge accommodated some remarkable changes. The MNR utilized two heavy

steel girders on these single lane bridges using 240 mm deep laminated decks. This is in contrast to the traditional four girders used with nailed decks of the same depth. The new prestressed deck can support a considerable increase in the girder spacing and the cantilever of the deck over the outside girder.

One other application of a transverse deck was performed in 1984 by Ontario Hydro. The access road to their Ragged Chutes generating station near Ottawa contains a series of 38 simple span steel girder bridges. These bridges supported old heavy railway ties with wood plank running surfaces. The deteriorated old ties were removed in panels, as shown in Figure 18, and replaced with prefabricated, prestressed deck panels, as shown in Figure 19. These new panels had the curbs and guard rail posts already installed. This unique approach resulted in a considerable reduction in the time required for field construction there by limiting the bridge closure to relatively short intervals. Flex seal joints were used to join the panels together at the opposing steel channels used for the prestressing anchorages. These seals prevent direct access of moisture and debris onto the exposed anchorages of the bars. Though it proved to be a relatively efficient approach, the additional steel required for the numerous steel bulkheads and the sealed joints resulted in a higher than usual construction cost of about \$450 per square metre. This cost included a new asphalt wearing surface, curbs and guard rails.

5/ SUMMARY

The prestressed wood deck system is growing in popularity and steadily replacing the traditional nailed system. The new deck is stiffer, stronger and considerably more durable under the effects of repeated loads. It can support a continuous wearing surface without cracking unlike the nailed system which generally requires continuous maintenance.

Though the new deck system can be more expensive per unit of deck because of the higher degree of sophistication required, the overall costs are usually less, due to the improved structural performance which reduces the required size of other structural components.

The flexibility of its application in various situations has only been touched upon by this paper. The MTC has a number of on-going research and development programs aimed at utilizing the concept even more for new construction. These projects include the use of longitudinal decks made composite with longitudinal steel girders and the integration of low profile prefabricated wood trusses into a multiple box-like prestressed system. Both of these ideas are aimed at creating longer span bridges which utilize wood as an efficient and economical structural system.

6/ REFERENCES

- [1] Taylor, R.J., Csagoly, P.F., 1979. Transverse Post-Tensioning of Longitudinally Laminated Timber Bridge Decks, Ontario Ministry of Transportation and Communications, RR 220.
- [2] Taylor, R.J., Batchelor, Dev.B, VanDalen, K., 1982. Prestressed Wood Bridges, Ontario Ministry of Transportation and Communications, SRR-83-01.
- [3] Ontario Ministry of Transportation and Communications, 1983. Ontario Highway Bridge Design Code.
- [4] Taylor, R.J., Revised 1984. Design of Prestressed Wood Bridges Using the Ontario Highway Bridge Design Code, Ontario Ministry of Transportation and Communications, SRR-83-03.
- [5] Taylor, R.J., 1984. A Prototype Prestressed Wood Bridge, Ontario Ministry of Transportation and Communications, SRR-83-07.
- [6] Taylor, R.J., 1986. Load Testing and Rehabilitation of the Sioux Narrows Bridge, Ontario Ministry of Transportation and Communications, SRR-86-04.

Table 1/ Bridges Rehabilitated by Transverse Prestressing

BRIDGE AND LOCATION	FIGURE	
	YEAR	
Hebert Creek, North Bay, Ontario	1976	4 to 8
Waterford Pond, Simcoe, Ontario	1979	-
Kabaigon River, Atikokan, Ontario	1979	9 to 11
Municipal, Prince Rupert, B.C.	1980	-
North Pagwatchuan, GERALTON, Ontario	1981	-
Pickrel River, Atikokan, Ontario	1982	12
Tomstown, North Bay, Ontario	1985	-
Valentine Creek, Hearst, Ontario	1985	13
Trout Creek, Red Rock, Ontario	1986	-

(* where applicable)

Table 2/ New Prestressed Wood Decks

BRIDGE AND LOCATION	YEAR	DECK TYPE	MAIN STRUCTURE	TOTAL STRUCTURE LENGTH	FIG *
Fox Lake Rd, Sudbury, Ontario	1981	N,LL	Frame	13 m	14
Sioux Narrows, Kenora, Ontario	1982	DR,LL	WT	120 m	15
Aquasabon River, Terrace Bay, Ontario	1983	N,TL	SG	43 m	19
Dorfl-Brick, Switzerland	1984	N,LL	WA	31 m	-
Gargantua, Mitchipicoten, Ontario	1984	N,LL	Footbridge	19.5 m	-
Ragged Chutes, Ottawa, Ontario	1984	DR,TL	SG	300 m	21
Laura Secord, St. Catherines, Ontario	1985	DR,LL	ST	60 m	17
East Abinette R., Mitchipicoten, Ont.	1985	N,TL	SG	16 m	-
Little Current, Little Current, Ont.	1986	DR,LL	ST	173 m	-
Witch Doctor, Mitchipicoten, Ontario	1986	N,TL	SG	16 m	-
Makobie R., New Liskeard, Ontario	1986	DR,LL	Deck	60 m	-

N = New, DR = Deck Replacement, LL = Longitudinal Laminated, TL = Transverse Laminated, SG = Steel Girders, ST = Steel Truss, WT = Wood Truss, WA = Wood Arc (* where applicable).

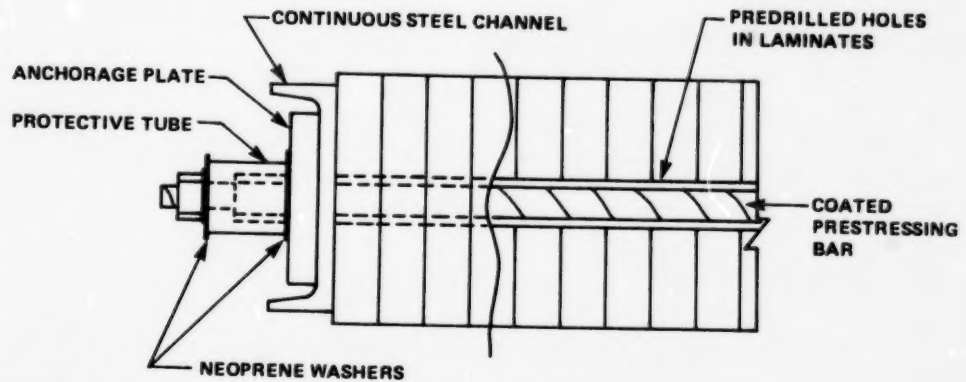


Figure 1/ Internal Prestressing System

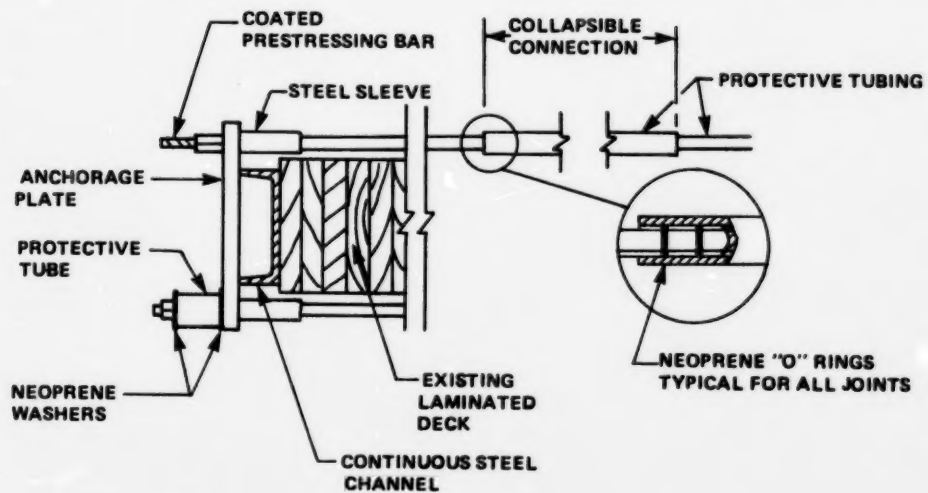


Figure 2/ External Prestressing System

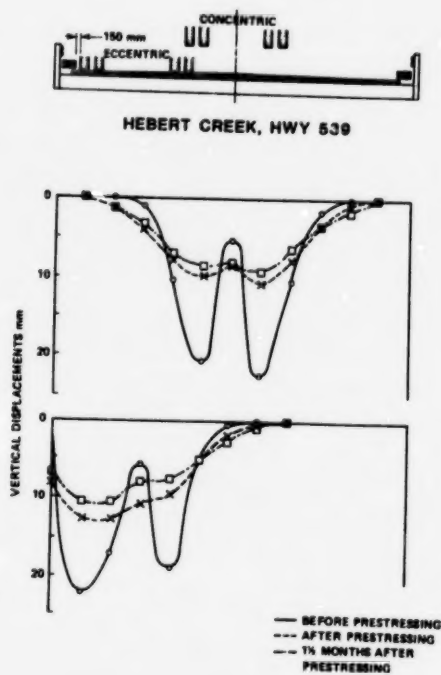


Figure 3/ Load Test Results, Hebert Creek Bridge



Figure 4/ Grooves Cut In Asphalt Surface



Figure 5/ Deck Anchorage to Supports

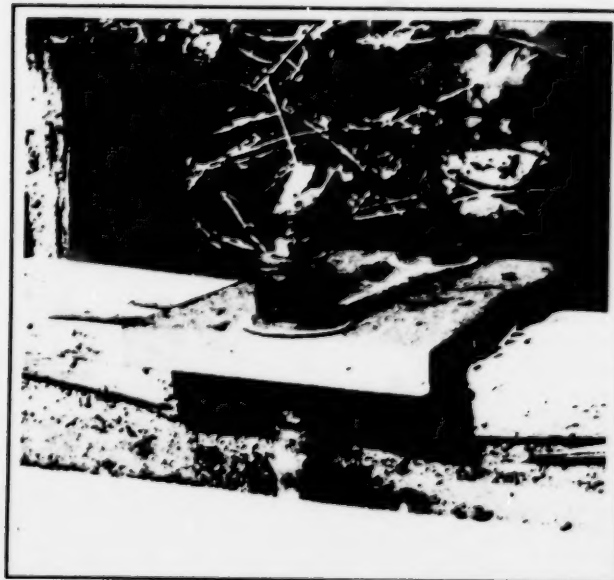


Figure 6/ Local Crushing of Timber



Figure 7/ Steel Channel Bulkhead

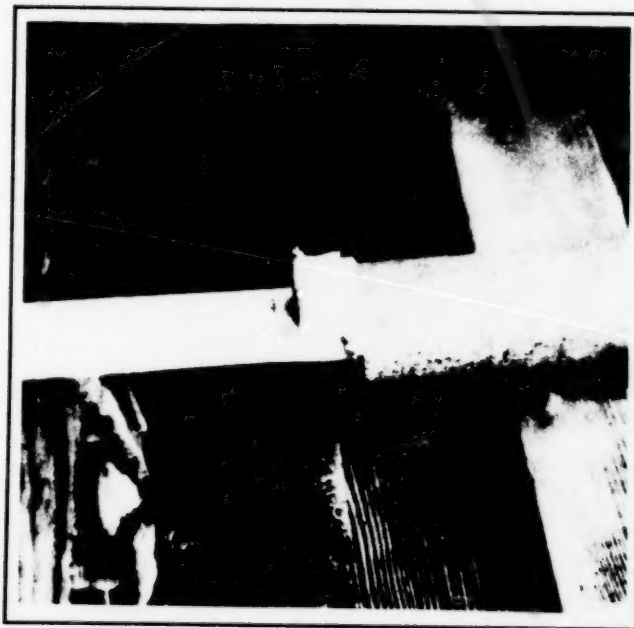


Figure 8/ Binding of Protective Tubing



Figure 9/ Flooding of Watertight Deck



Figure 10/ Temporary Running Plank Surface

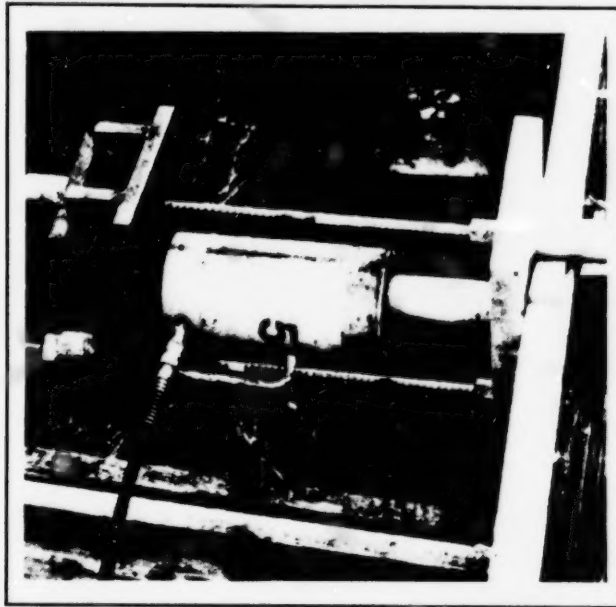


Figure 11/ Hydraulic Jacking, External Prestressing System

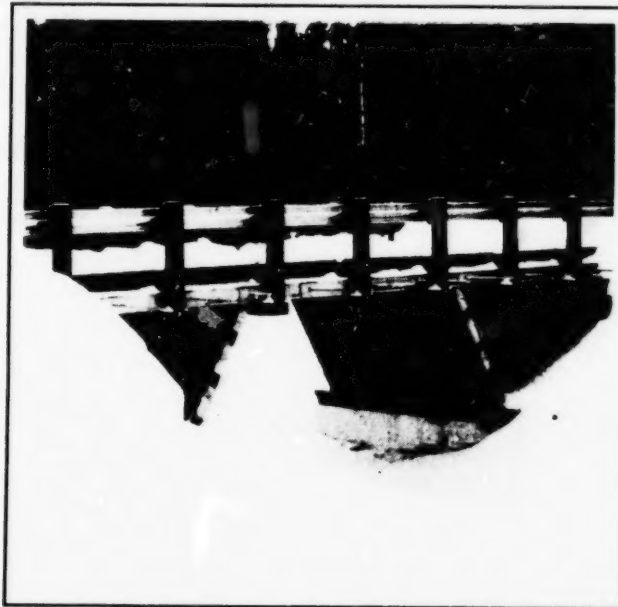


Figure 12/ Fox Lake Road Bridge



Figure 13/ Individual Laminate Frames



Figure 14/ Hydraulic Jacking, Internal Prestressing System



Figure 15/ Deck Replacement, Sioux Narrows Bridge

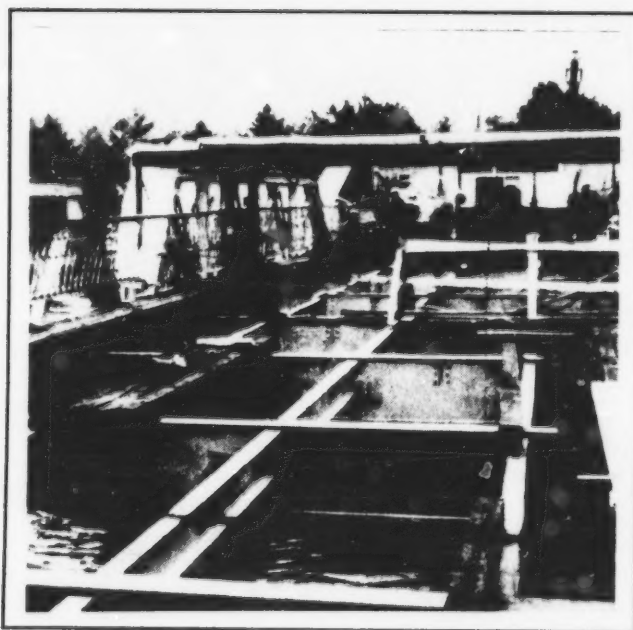


Figure 16/ Deck Replacement, Laura Secord Bridge

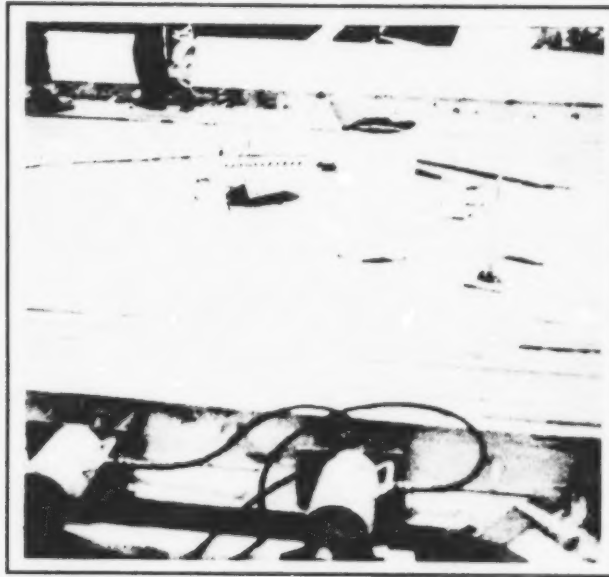


Figure 17/ Deck Replacement, Aquasaban River Bridge

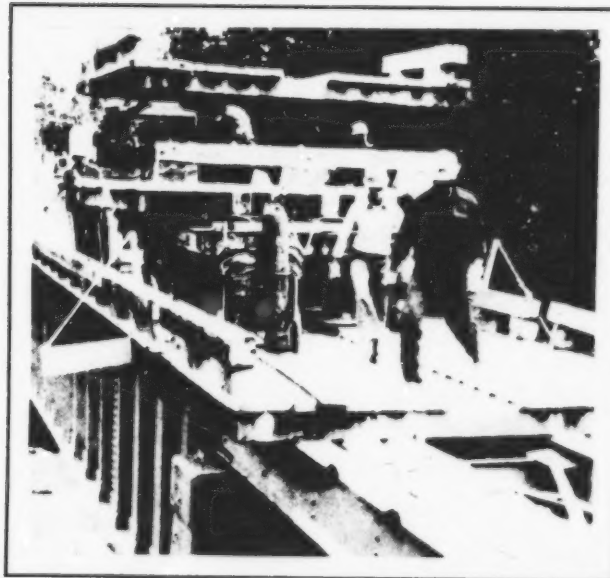


Figure18/ Sectional Removal of Old Deck



Figure 19/ New Prefabricated Prestressed Deck Panels